[5G-ACIA] Email discussion

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Title: 5G-ACIA evaluations - 2nd round of simulation results

# Discussion

In the RAN#89-e meeting, RAN discussed the LS from 5G-ACIA on Rel-16 URLLC and IIoT performance evaluation [1], and approved a way forward in [2].

During October 12-16, the simulation assumptions and URLLC features for evaluation were discussed, with reaching the following agreements.

**Agreements:**

* The simulation assumptions given in the table are agreed
* Additional simulation parameters are taken from TR 38.824.

|  |  |  |
| --- | --- | --- |
| Parameters | 5G-ACIA LS | **Agreement** |
| Factory hall size | 120x50 m | As in 5G-ACIA LS |
| Room height | 10 m | As in 5G-ACIA LS |
| Inter-BS/TRP distance | Depending on the number of TRPs, which are evenly deployed in the factory hall. Simulation company should provide the number of BSs/TRPs used in the simulation. | According to proposed layout below |
| BS/TRP antenna height | 1.5 m for InF-SL and InF-DL 8m for InF-SH and InF-DH | As in 5G-ACIA LS |
| Layout – BS/TRP deployment | Depending on the number of TRPs | 12 TRPs within area with the same 2D placement as in TR 38.901 and TR 38.824. |
| Channel model | UC-2: InF-DH > InD-DL > InF-SH > InF-SL | Mandatory: InF-DH  Optional: InD-DL, InF-SH, InF-SL |
| Carrier frequency and simulation bandwidth | TDD 4 GHz: 100 MHz 30 GHz: 160 MHz | As in 5G-ACIA LS |
| TDD DL-UL configuration | Simulation company should report the used DL-UL configuration. | Companies should report the used DL-UL configuration. 1:1 DL-UL configuration is recommended. |
| Number of UEs per service area | Up to 50 per service area, e.g., 10, 20, 40, and 50 | As in 5G-ACIA LS |
| UE distribution | All UEs randomly distributed within the respective service area. | As in 5G-ACIA LS |
| Message size | 48 bytes | 48 bytes |
| DL traffic model | DL traffic arrival with option-1, option-2, and option-3. | 5G-ACIA Option 1 is mandatory. Companies are also encouraged to provide results for option 3 |
| UL traffic model | UL traffic is symmetric with DL, and DL-UL traffic arrival time relationship with option-1 and option-2 | As in 5G-ACIA LS with Option 1 as mandatory |
| CSA requirements | UC-#2: 99.9999% | UC-#2: 99.9999% |
| Performance metrics | 1) CSA: single CDF of CSA distribution of all UEs in factory hall 2) Latency: single CDF of latency distribution of all UEs in factory hall 3) Percentage of UEs satisfying requirements  4) resource utilization | As in 5G-ACIA LS with 3) and 4) as low priority  Note: For metric 2) it is clarified that a packet transmission cannot be performed after the latency deadline. The collected statistics cannot exceed the latency requirement. The packets exceeding the deadline are visible in the UE packet error statistics |
| E2E latency & air interface latency | E2E latency: 1 ms for UC#2 | E2E latency: 1 ms for UC#2  Air interface latency: 1ms |
| UE speed | Linear movement | Linear movement: 75 km/h  No explicit UE mobility (nor handovers) are modeled in the evaluations. |
| BS antenna mount |  | Option 1 (1 sector per BS) from 38.824 is used |

During December 14-18, companies provided the first round of simulation results and reached the following conclusions after the first round of discussion[3].

Conclusion on collecting simulation assumptions:

* The final Excel sheet can be found [here](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_91e/Inbox/Drafts/5G-ACIA%20December/Final%20Summary/Simulation%20assumptions%20for%20calibration%20Final.xlsx).

Conclusion on FR2 antenna assumptions:

* 2RX/TX is still the baseline
* Results for additional configurations can be provided

Conclusion on cell coordination:

* No coordination is baseline
* Results with cell coordination can be provided

Conclusion on MU-MIMO:

* SU-MIMO is baseline
* Results with MU-MIMO can be provided

Agreement for latency:

* For FR1 companies are encouraged to provide simulation results for one-shot transmission

Noted proposal for latency

* For the E2E latency, following assumptions are made:
  + Components from table 5.7.1.1.1.-1 for DL and table 5.7.1.1.2.-1 for UL from TR 37.910 are used to calculate the E2E latency
    - In case re-tx is simulated, the alignment delay for the re-TX at the gNB side (which is not included in the tables from the TR 37.910) should also be added to the latency
  + Companies report the UE processing delay and gNB processing delay, for other components, the values from table 5.7.1.1.1.-1 for DL and table 5.7.1.1.2.-1 for UL from TR 37.910 are assumed

Conclusion on additional simulation assumptions:

* No consensus on CSA metric with no consecutive errors is mandatory
* Narrow down channel model to InF-DH explicitly
* Option-1 for DL traffic and Option-1 for UL traffic relationship to DL is still baseline. Additional results can be submitted
* Number of samples, minimum number of packets per UE and minimum number of UEs / network drops modelled are left to companies’ choice

Conclusions on format for submissions to round 2:

* Companies will provide
  + CDF of packet error rate for UL and DL
  + CDF of CSA for UL and DL
  + Tabulated values for percentage of UEs satisfying 1ms latency and 99.9999% reliability/CSA requirement for each simulated case
  + CDF for coupling loss and geometry for calibration

In this contribution, we provide the second round simulation results for 5G-ACIA evaluation.

# Evaluation for FR1

## Calibration

The coupling loss and geometry SINR for DL are presented below for calibration purposes.



Figure 1 CDF of the coupling loss and geometry SINR for DL

## Frame structure and latency analysis

1:1 DL-UL configuration with ‘DDDDDDGGUUUUUU’ is assumed in our evaluation. Regarding the signaling overhead, one DL symbol per slot is used for PDCCH and one UL symbol per slot is assumed for PUCCH/SRS transmission. Additionally, 4 REs are used to transmit DMRS at each transmission occasion. Thus, 5-symol DL/UL duration is assumed for scheduling SPS PDSCH/CG PUSCH respectively.

Figure 2 shows the frame structure assumed in our evaluation. More detailed simulation assumptions are given in Appendix.



Figure 2 Frame structure assumed in evaluation for FR1

For DL transmission, the latency analysis from BS side to UE side is shown in Table 1 based on TR 37.910.

Table 1 Latency analysis based on TR 37.910 for FR1 for DL

|  |
| --- |
| The preparation time at the gNB(T1): N2/2 = 2.75sym  The alignment delay at the gNB(T2): 0.25~13.25sym  The transmission time of PDSCH(T3): 5sym  The decoding time of the transmission(T4): N1/2 = 2.25sym  Maximum delay: 2.75+13.25+5+2.25 = 23.25sym ≈ 0.83ms  Minimum delay: 2.75+0.25+5+2.25 = 10.25sym ≈ 0.37ms  Note that, if the processing time is based on TR 38.824, similar observation can be obtained. |

The latency analysis for one shot transmission with data arrival at each symbol is provided in Table 2. As can be observed, the maximum delay is about 0.83ms for one shot transmission. It can be easily inferred that the latency would exceed 1 ms second for one initial transmission and one re-transmission. Note that, if the processing time is based on TR 38.824, similar observation can be obtained.

Table 2 Latency analysis for one shot transmission with data arrival at each symbol in a slot based on TR 37.910.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Symbol** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| T1 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| T2 | 11.25 | 10.25 | 9.25 | 8.25 | 7.25 | 6.25 | 5.25 | 4.25 | 3.25 | 2.25 | 1.25 | 0.25 | 13.25 | 12.25 |
| T3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| T4 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 |
| All | 21.25 | 20.25 | 19.25 | 18.25 | 17.25 | 16.25 | 15.25 | 14.25 | 13.25 | 12.25 | 11.25 | 10.25 | 23.25 | 22.25 |

In addition, the similar observation can be obtained for UL user plan latency.

***Observation 1:*** *For DL-UL configuration with ‘DDDDDDGGUUUUUU’ in FR1, the latency of one shot transmission for both DL and UL is smaller than the 1 ms requirement, while it would exceed 1ms if one additional re-transmission is considered.*

## Performance metrics

The agreed CSA requirement is 99.9999%. Since the CSA is derived from the probability of occurrence of two or more consecutive packet/TB reception errors, it needs to determine the target BLER for each TB transmission to derive CSA value. Since the survival time is equal to the packet arrival period, 1e-3 target BLER can be used in evaluation if uncorrelated packet error is assumed, Anyway, we also provide some results for 1e-6 target BLER for the sake of comprehensiveness.

In addition, we would like to highlight the following notes for the metrics used in our evaluation.

* For the metric of percentage of UEs satisfying requirements, the requirements here mean latency requirement (i.e., 1ms) and reliability requirement (i.e., 1-BLER).
* There is no packet segmentation in our evaluation, i.e., the target BLER of one TB is equal to the target packet error rate (PER).
* For CDF of latency in our evaluation, we take all generated packets into account including the one doesn’t satisfying the PER requirement or the one doesn’t have a chance to be transmitted. For these packets, the latency is regarded as 1.1ms deliberately.
* If one packet is not transmitted due to limited resources, the PER is regarded as 1.

The same performance metrics are used for FR1 and FR2.

## Evaluation results for 1e-3 target BLER

* + 1. **No cell coordination**

Assuming all the BS can use any of the RBs without any coordination, more than one UEs will be transmitted in a same RB, which will cause severe interference among UEs, especially in case the number of UEs per service area is large. Therefore, we provide the result of no cell coordination by the way that all RBs in the bandwidth are equally split to each BS in a predefined manner. If the number of RBs is not divisible by the number of BSs, the difference of RB number for any two BSs cannot be more than 1. That is, if the number of RB is 273 while the number of BSs is 12, then 23 RBs are allocated to the first nine BSs, and 22 RBs are allocated to the last three BSs.

In Table 3, the evaluation results including CSA, percentage of UEs satisfying requirements and RU are presented.

Table 3 Evaluations results(CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 1.72% |
| UL | 100% | 100% | 1.84% |
| 20 users | DL | 100% | 100% | 3.34% |
| UL | 100% | 100% | 3.68% |
| 40 users | DL | 100% | 68.75% | 7.48% |
| UL | 100% | 78.33% | 6.57% |

Note 1: Regarding the RU for each BS, it is calculated as the number of allocated RBs divided by the total number of RBs in the bandwidth (i.e., 273 RBs).

Note 2: Our scheduling strategy is to try to avoid consecutive packet errors. For instance, if the first packet fails the following-up packet would have higher priority by allocating sufficient resources to try to guarantee its successful transmission.

The CDF of PER and CDF of user plan latency for different number of uses per service area for DL are provided in Figure 3 and Figure 4 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area |

Figure 3 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area |

Figure 4 CDF of user plan latency for different number of uses per service area for DL

The CDF of PER and CDF of user plan latency for different number of uses per service area for UL are provided in Figure 5 and Figure 6 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area |

Figure 5 CDF of PER for different number of uses per service area for UL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area |

Figure 6 CDF of user plan latency for different number of uses per service area for UL

***Observation 2:***

* *For FR1 with 1e-3 target BLER and no cell coordination,* 
  + *If the number of UEs per service area is no more than 20, the CSA and percentage of UEs satisfying the requirements are 100% for both DL and UL.*
  + *If the number of UEs per service area is 40, the CSA is 100% for both DL and UL, while the percentage of UEs satisfying the requirements is 68.75% and 78.33% for DL and UL respectively.*
    1. **Cell coordination**

For cell coordination, we assume all 12 BSs can be fully coordinated. When the number of UEs is less than the number of RBs, the UEs could be FDMed to reduce interference. When the number of UEs is more than the number of RBs, two users can be transmitted in a same RB. In order to reduce the interference, the servicing BSs for these two users should be as far away as possible. To further ensure the performance of CSA, we use some scheduling strategies to avoid continuous packet errors for a same UE. Table 4 shows the evaluation results of cell coordination.

Table 4 Evaluations results (CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 2.22% |
| UL | 100% | 100% | 1.84% |
| 20 users | DL | 100% | 100% | 4.68% |
| UL | 100% | 100% | 3.68% |
| 40 users | DL | 100% | 100% | 9.01% |
| UL | 100% | 100% | 7.35% |
| 50 users | DL | 100% | 72.67% | 12.07% |
| UL | 100% | 98.67% | 9.23% |

The CDF of PER and CDF of user plan latency for different number of uses per service area for DL are provided in Figure 7 and Figure 8 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 7 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 8 CDF of user plan latency for different number of uses per service area for DL

The CDF of PER and CDF of user plan latency for different number of uses per service area for UL are provided in Figure 9 and Figure 10 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 9 CDF of PER for different number of uses per service area for UL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 10 CDF of user plan latency for different number of uses per service area for UL

***Observation 3:***

* *For FR1 with 1e-3 target BLER and cell coordination,* 
  + *If the number of UEs per service area is no more than 40, the CSA and percentage of UEs satisfying the requirements are 100% for both DL and UL.*
  + *If the number of UEs per service area is 50, the CSA is 100% for both DL and UL, while the percentage of UEs satisfying the requirements is 72.67% and 98.67% for DL and UL respectively.*

## Evaluation results for 1e-6 target BLER

* + 1. **No cell coordination**

In this section, we also evaluated the case for TargetBLER=1e-6. The evaluation results of CSA, percentage of UEs satisfying requirements and RU are presented in following Table 5.

Table 5 Evaluations results (CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 2.21% |
| UL | Figure 14 | 96.67% | 1.84% |
| 20 users | DL | Figure 11 | 97.5% | 4.29% |
| UL | - | - | - |

The CDF of CSA, PER and user plan latency for different number of uses per service area for DL are provided in Figure 11, Figure 12 and Figure 13 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 11 CDF of CSA for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 12 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 13 CDF of user plan latency for different number of uses per service area for DL

The CDF of CSA, PER and user plan latency for 10 uses per service area for UL are provided in Figure 14.

|  |
| --- |
| 10 UEs per service area |

Figure 14 CDF of CSA, PER and latency for 10 uses per service area for UL

***Observation 4:***

* *For FR1 with 1e-6 target BLER and no cell coordination,* 
  + *For DL, if the number of UEs per service area is 10, the CSA and percentage of UEs satisfying the requirements are 100% If the number of UEs per service area is 20, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 97.5%.*
  + *For UL, if the number of UEs per service area is 10, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 96.67%*
    1. **Cell coordination**

For cell coordination, we also evaluated the case for TargetBLER=1e-6. The evaluation results of CSA, percentage of UEs satisfying requirements and RU are presented in following Table 6.

Table 6 Evaluations results (CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 2.22% |
| UL | 100% | 98.33% | 1.84% |
| 20 users | DL | 100% | 100% | 4.29% |
| UL | 100% | 97.5% | 3.68% |
| 40 users | DL | Figure 15 | 98.44% | 9.01% |
| UL | Figure 18 | 96.67% | 7.35% |

The CDF of CSA, PER and user plan latency for different number of uses per service area for DL are provided in Figure 15, Figure 16 and Figure 17 respectively.

|  |
| --- |
| 20 UEs per service area 40 UEs per service area |

Figure 15 CDF of CSA for different number of uses per service area for DL

|  |
| --- |
| 20 UEs per service area 40 UEs per service area |

Figure 16 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 20 UEs per service area 40 UEs per service area |

Figure 17 CDF of user plan latency for different number of uses per service area for DL

The CDF of CSA, PER and user plan latency for different number of uses per service area for DL are provided in Figure 18, Figure 19 and Figure 20 respectively.

|  |
| --- |
| 20 UEs per service area 40 UEs per service area |

Figure 18 CDF of CSA for different number of uses per service area for UL

|  |
| --- |
| 20 UEs per service area 40 UEs per service area |

Figure 19 CDF of PER for different number of uses per service area for UL

|  |
| --- |
| 20 UEs per service area 40 UEs per service area |

Figure 20 CDF of user plan latency for different number of uses per service area for UL

Based on above evaluation results of FR1, we have the following observation.

***Observation 5:***

* *For FR1 with 1e-6 target BLER and cell coordination,* 
  + *For DL, if the number of UEs per service area is no more than 20, the CSA and percentage of UEs satisfying the requirements are 100%. If the number of UEs per service area is 40, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 98.44%.*
  + *For UL, if the number of UEs per service area is no more than 20, the CSA is 100%, while the percentage of UEs satisfying the requirements is 98.33% and 97.5% for 10 UEs and 20 UEs per service area respectively. If the number of UEs per service area is 40, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 96.67%.*

# Evaluation for FR2

## Calibration

The coupling loss and DL geometry SINR without beam selection at UE side are presented below for calibration purposes.



Figure 21 CDF of the coupling loss and DL geometry SINR without UE side beam selection

The coupling loss and DL geometry SINR with beam selection at UE side are presented in below Figure 22. Our simulation results for FR2 are based on enabling UE side beam selection.



Figure 22 CDF of the coupling loss and DL geometry SINR with UE side beam selection

## Frame structure and latency analysis

The frame structure and overhead are the same with FR1, which is also shown in Figure 23.



Figure 23 Frame structure assumed in evaluation for FR2

For DL transmission, the latency analysis from BS side to UE side is shown in Table 7 based on TR 37.910 and TR 38.824. From this result, we can see that FR2 can enable one HARQ-ACK retransmission for DL with a maximum of 102-symbol latency which is smaller than the 1ms latency requirement.

Table 7 Latency analysis based on TR 37.910 and TR 38.824

|  |
| --- |
| The preparation time at the gNB(T1): N2/2 + X = 20/2 + 8 = 18sym  The alignment delay at the gNB(T2): 0~13sym  The transmission time of PDSCH(T3): 5sym  The decoding of PDSCH and preparation of PUCCH carrying ACK/NACK(T5): N1 = 20sym  The alignment delay for PUCCH transmission(T6): 1sym  The transmission time of PUCCH(T7): 1sym  The decoding time PUCCH and the preparation time of PDCCH and PDSCH at the gNB(T8): N2 + X = 20 + 8 = 28sym  The alignment delay at the gNB for retransmission at BS(T9): 0sym  The transmission time of PDCCH and PDSCH(T10): 6sym  The decoding time of the retransmission(T4): N1/2 = 20/2 = 10sym  Maximum delay: 18+13+5+20+1+1+28+0+6+10 = 102sym ≈ 0.91ms |

The latency analysis for one initial and one re-transmission with data arrival at each symbol for DL is given in Table 8.

Table 8 Latency analysis for one initial and one re-transmission with data arrival at each symbol in a slot for DL TR 37.910 and TR 38.824

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Symbol** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| T1 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| T2 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 13 | 12 | 11 |
| T3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| T5 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| T6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| T7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| T8 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| T9 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 | 6/0 |
| T10 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| T4 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| All | 99 | 98 | 97 | 96 | 95 | 94 | 93 | 92 | 91 | 90 | 89 | 102 | 101 | 100 |

With similar latency analysis for UL, we find that re-transmission cannot be enabled for UL otherwise it will exceed the 1ms requirement.

***Observation 6:*** *For DL-UL configuration with ‘DDDDDDGGUUUUUU’ in FR2, the DL latency can satisfy the 1ms requirement even with enabling one re-transmission, while it would exceed 1ms for UL if one re-transmission is considered.*

Therefore, one re-transmission is enabled for DL while one shot transmission is used for UL in our evaluation for FR2.

## Evaluation results for 1e-3 target BLER

* + 1. **No cell coordination**

For FR2 with no cell coordination, we assume the same methodology as FR1. In Table 9, the evaluation results including CSA, percentage of UEs satisfying requirements and RU are presented.

Table 9 Evaluations results (CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 2.24% |
| UL | 100% | 100% | 2.35% |
| 20 users | DL | Figure 24 | 95.83% | 3.54% |
| UL | Figure 25 | 97.5% | 4.72% |



Figure 24 CDF of CSA for 20 UEs per service area for DL



Figure 25 CDF of CSA for 20 UEs per service area for UL

The CDF of PER and CDF of user plan latency for different number of uses per service area for DL are provided in Figure 26 and Figure 27 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 26 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 27 CDF of user plan latency for different number of uses per service area for DL

The CDF of PER and CDF of user plan latency for different number of uses per service area for UL are provided in Figure 28 and Figure 29 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 28 CDF of PER for different number of uses per service area for UL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 29 CDF of user plan latency for different number of uses per service area for UL

***Observation 7:***

* *For FR2 with 1e-3 target BLER and no cell coordination,* 
  + *If the number of UEs per service area is 10, the CSA and percentage of UEs satisfying the requirements are 100% for both DL and UL.*
  + *If the number of UEs per service area is 20, the CSA cannot satisfy the 99.9999% requirements for both DL and UL, and the percentage of UEs satisfying the requirements is 95.83% and 97.5% for DL and UL respectively.*
    1. **Cell coordination**

For FR2 with cell coordination, we assume the same methodology as FR1. Table 10 shows the evaluation results of cell coordination.

Table 10 Evaluations results (CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 2.06% |
| UL | 100% | 100% | 2.35% |
| 20 users | DL | 100% | 100% | 3.41% |
| UL | Figure 30 | 98.33% | 4.72% |
| 40 users | DL | 100% | 99.58% | 7.89% |
| UL | - | - | - |
| 50 users | DL | Figure 31 | 93.33% | 12.12% |
| UL | - | - | - |



Figure 30 CDF of CSA for 20 UEs per service area for UL



Figure 31 CDF of CSA for 50 UEs per service area for DL

The CDF of PER and the CDF of user plan latency for different number of uses per service area for DL are provided in Figure 32 and Figure 33.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 32 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 33 CDF of user plan latency for different number of uses per service area for DL

The CDF of PER and the CDF of user plan latency for different number of uses per service area for UL are provided in Figure 34 and Figure 35.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 34 CDF of PER for different number of uses per service area for UL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area |

Figure 35 CDF of user plan latency for different number of uses per service area for UL

***Observation 8:***

* *For FR2 with 1e-3 target BLER and cell coordination,* 
  + *For DL, if the number of UEs per service area is no more than 40, the CSA is 100%. If the number of UEs per service area is 50, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 99.58%.*
  + *For UL, if the number of UEs per service area is no more than 10, the CSA is 100%. If the number of UEs per service area is 20, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 98.33%.*

## Evaluation results for 1e-6 target BLER

* + 1. **No cell coordination**

In this section, we also evaluated the case for TargetBLER=1e-6 for FR2 without cell coordination. The evaluation results of CSA, percentage of UEs satisfying requirements and RU are presented in following Table 11.

Table 11 Evaluations results(CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | Figure 36 | 92.50% | 2.57% |
| UL | Figure 36 | 96.67% | 2.35% |

|  |
| --- |
| 10 UEs per service area |

Figure 36 CDF of CSA for 10 uses per service area for DL and UL

The CDF of PER for 10 uses per service area for DL and UL are provided in Figure 37.

|  |
| --- |
| 10 UEs per service area |

Figure 37 CDF of PER for 10 uses per service area for DL and UL

The CDF of user plan latency for 10 uses per service area for DL and UL are provided in Figure 38.

|  |
| --- |
| 10 UEs per service area |

Figure 38 CDF of user plan latency for 10 uses per service area for DL and UL

***Observation 9:***

* *For FR2 with 1e-6 target BLER and no cell coordination,* 
  + *Even if the number of UEs per service area is 10, the CSA cannot satisfy the 99.9999% requirements for both DL and UL, and the percentage of UEs satisfying the requirements is 92.50% and 96.67% for DL and UL respectively.*
    1. **Cell coordination**

For cell coordination, we also evaluated the case for TargetBLER=1e-6. The evaluation results of CSA, percentage of UEs satisfying requirements and RU are presented in following Table 12.

Table 12 Evaluations results (CSA, percentage of UEs satisfying requirements and RU)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Number of UEs per service area | DL/UL | CSA | Percentage of UEs satisfying requirements | RU |
| 10 users | DL | 100% | 100% | 2.60% |
| UL | Figure 39 | 98.33% | 2.35% |
| 20 users | DL | 100% | 100% | 4.29% |
| UL | - | - | - |
| 40 users | DL | 100% | 96.46% | 9.13% |
| UL | - | - | - |
| 50 users | DL | Figure 40 | 69.33% | 14.31% |
| UL | - | - | - |

|  |
| --- |
|  |

Figure 39 CDF of CSA for 10 uses per service area for UL

|  |
| --- |
| 40 UEs per service area 50 UEs per service area |

Figure 40 CDF of CSA for different number of uses per service area for DL

The CDF of PER and CDF of user plan latency for different number of uses per service area for DL are provided in Figure 41 and Figure 42 respectively.

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 41 CDF of PER for different number of uses per service area for DL

|  |
| --- |
| 10 UEs per service area 20 UEs per service area    40 UEs per service area 50 UEs per service area |

Figure 42 CDF of user plan latency for different number of uses per service area for DL

The CDF of PER and latency for 10 uses per service area for UL is provided in Figure 43.

|  |
| --- |
| 10 UEs per service area |

Figure 43 CDF of PER and latency for 10 uses per service area for UL

Based on above evaluation results of FR2, we have the following observation.

***Observation 10:***

* *For FR2 with 1e-6 target BLER and cell coordination,* 
  + *For DL, if the number of UEs per service area is no more than 40, the CSA is 100%. If the number of UEs per service area is 50, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 69.33%.*
  + *For UL, even if the number of UEs per service area is 10, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 98.33%.*

# Conclusion

***Observation 1:*** *For DL-UL configuration with ‘DDDDDDGGUUUUUU’ in FR1, the latency of one shot transmission for both DL and UL is smaller than the 1 ms requirement, while it would exceed 1ms if one additional re-transmission is considered.*

***Observation 2:***

* *For FR1 with 1e-3 target BLER and no cell coordination,* 
  + *If the number of UEs per service area is no more than 20, the CSA and percentage of UEs satisfying the requirements are 100% for both DL and UL.*
  + *If the number of UEs per service area is 40, the CSA is 100% for both DL and UL, while the percentage of UEs satisfying the requirements is 68.75% and 78.33% for DL and UL respectively.*

***Observation 3:***

* *For FR1 with 1e-3 target BLER and cell coordination,* 
  + *If the number of UEs per service area is no more than 40, the CSA and percentage of UEs satisfying the requirements are 100% for both DL and UL.*
  + *If the number of UEs per service area is 50, the CSA is 100% for both DL and UL, while the percentage of UEs satisfying the requirements is 72.67% and 98.67% for DL and UL respectively.*

***Observation 4:***

* *For FR1 with 1e-6 target BLER and no cell coordination,* 
  + *For DL, if the number of UEs per service area is 10, the CSA and percentage of UEs satisfying the requirements are 100% If the number of UEs per service area is 20, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 97.5%.*
  + *For UL, if the number of UEs per service area is 10, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 96.67%*

***Observation 5:***

* *For FR1 with 1e-6 target BLER and cell coordination,* 
  + *For DL, if the number of UEs per service area is no more than 20, the CSA and percentage of UEs satisfying the requirements are 100%. If the number of UEs per service area is 40, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 98.44%.*
  + *For UL, if the number of UEs per service area is no more than 20, the CSA is 100%, while the percentage of UEs satisfying the requirements is 98.33% and 97.5% for 10 UEs and 20 UEs per service area respectively. If the number of UEs per service area is 40, the CSA cannot satisfy the 99.9999% requirements, and the percentage of UEs satisfying the requirements is 96.67%.*

***Observation 6:*** *For DL-UL configuration with ‘DDDDDDGGUUUUUU’ in FR2, the DL latency can satisfy the 1ms requirement even with enabling one re-transmission, while it would exceed 1ms for UL if one re-transmission is considered.*

***Observation 7:***

* *For FR2 with 1e-3 target BLER and no cell coordination,* 
  + *If the number of UEs per service area is 10, the CSA and percentage of UEs satisfying the requirements are 100% for both DL and UL.*
  + *If the number of UEs per service area is 20, the CSA cannot satisfy the 99.9999% requirements for both DL and UL, and the percentage of UEs satisfying the requirements is 95.83% and 97.5% for DL and UL respectively.*

***Observation 8:***

* *For FR2 with 1e-3 target BLER and cell coordination,* 
  + *For DL, if the number of UEs per service area is no more than 40, the CSA is 100%. If the number of UEs per service area is 50, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 99.58%.*
  + *For UL, if the number of UEs per service area is no more than 10, the CSA is 100%. If the number of UEs per service area is 20, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 98.33%.*

***Observation 9:***

* *For FR2 with 1e-6 target BLER and no cell coordination,* 
  + *Even if the number of UEs per service area is 10, the CSA cannot satisfy the 99.9999% requirements for both DL and UL, and the percentage of UEs satisfying the requirements is 92.50% and 96.67% for DL and UL respectively.*

***Observation 10:***

* *For FR2 with 1e-6 target BLER and cell coordination,* 
  + *For DL, if the number of UEs per service area is no more than 40, the CSA is 100%. If the number of UEs per service area is 50, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 69.33%.*
  + *For UL, even if the number of UEs per service area is 10, the CSA cannot satisfy the 99.9999% requirements and percentage of UEs satisfying the requirements is 98.33%.*

# Reference

1. 3GPP RAN1#102-e, R1-2006953, LS on 3GPP NR Rel-16 URLLC and IIoT performance evaluation, 5G ACIA.
2. 3GPP RAN#89-e, RP-202069, Way forward and RAN work for 5G ACIA requested simulations, Ericsson.
3. 3GPP RAN#90-e, [Inbox](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_90e/Inbox/) / [Drafts](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_90e/Inbox/Drafts/) / 5G-ACIA December / Draft summary / 5G-ACIA Week 2 - Final summary, Ericsson.

# Appendix

Table A-1 Simulation assumptions for 4GHz

|  |  |
| --- | --- |
| Parameter | Assumption |
| Factory hall size | 120x50 m |
| Room height | 10 m |
| Layout – BS/TRP deployment | Single layer as defined in 38.802  Indoor floor:12 BSs per 120 m x 50 m |
| BS/TRP antenna height | 8m for InF-DH |
| Channel model | InF-DH |
| Carrier frequency and simulation bandwidth | TDD 4 GHz: 100 MHz |
| TDD DL-UL configuration | DDDDDDGGUUUUUU |
| Number of UEs per service area | Up to 50 per service area, e.g., 10, 20, 40, and 50 |
| UE distribution | All UEs randomly distributed within the respective service area. |
| Message size | 48 bytes |
| DL traffic model | Option 1, i.e., all UEs’ DL messages arriving at NG-RAN node in the first transfer interval are  uniformly random distributed within the TI time window. |
| UL traffic model | Same as DL |
| CSA requirements | UC-#2: 99.9999% |
| Performance metrics | 1. CSA: single CDF of CSA distribution of all UEs in factory hall 2. Latency: single CDF of latency distribution of all UEs in factory hall 3. Percentage of UEs satisfying requirements. The requirements here mean latency requirement (i.e., 1ms) and reliability requirement (i.e., 1-BLER or 1- PER) 4. Resource utilization 5. Packet error rate |
| E2E latency & user plan latency | 1 ms for UC#2 |
| UE speed | Linear movement |
| BS antenna mount | Option 1 (1 sector per BS) from 38.824 is used |
| Carrier frequency | 4 GHz |
| UE Tx power | 23dBm |
| BS antenna element gain + connector loss | 5 dBi |
| BS receiver noise figure | 5dB |
| BS antenna configurations | 4 Tx/4 Rx antenna ports  (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) for 4 Tx/4 Rx antenna ports;  dH = dV = 0.5 λ |
| UE antenna configuration | 2 Tx/4 Rx antenna ports  Panel model 1: Mg = 1, Ng = 1, P = 2, dH = 0.5  (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) for 4 Rx;  (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1) for 2 Tx; |
| UE antenna height | Follow the modelling of TR 38.901 (e.g. 1.5m) |
| UE antenna gain | 0dBi as starting point |
| BS Tx power | 24 dBm per 20 MHz |
| BS receiver | MMSE-IRC as the baseline receiver |
| UE receiver noise figure | 9 dB |
| SCS | 30 kHz |
| Channel estimation | Ideal |
| UE power control | P0= -60; alpha = 0.6 |

Table A-2 Simulation assumptions for 30GHz

|  |  |
| --- | --- |
| Parameter | Assumption |
| Factory hall size | 120x50 m |
| Room height | 10 m |
| Layout – BS/TRP deployment | Single layer as defined in 38.802  Indoor floor:12 BSs per 120 m x 50 m |
| BS/TRP antenna height | 8m for InF-DH |
| Channel model | InF-DH |
| Carrier frequency and simulation bandwidth | TDD 30 GHz: 160 MHz |
| TDD DL-UL configuration | DDDDDDGGUUUUUU |
| Number of UEs per service area | Up to 50 per service area, e.g., 10, 20, 40, and 50 |
| UE distribution | All UEs randomly distributed within the respective service area. |
| Message size | 48 bytes |
| DL traffic model | Option 1, i.e., all UEs’ DL messages arriving at NG-RAN node in the first transfer interval are  uniformly random distributed within the TI time window. |
| UL traffic model | Same as DL |
| CSA requirements | UC-#2: 99.9999% |
| Performance metrics | 1. CSA: single CDF of CSA distribution of all UEs in factory hall 2. Latency: single CDF of latency distribution of all UEs in factory hall 3. Percentage of UEs satisfying requirements 4. resource utilization 5. Packet error rate |
| E2E latency & air interface latency | E2E latency: 1 ms for UC#2 |
| UE speed | Linear movement |
| BS antenna mount | Option 1 (1 sector per BS) from 38.824 is used |
| UE Tx power | 23dBm |
| BS antenna element gain + connector loss | 5 dBi |
| BS receiver noise figure | 7dB |
| BS antenna configurations | 4 Tx/4 Rx antenna ports  (M, N, P, Mg, Ng; Mp, Np) = (4, 4, 2, 1, 1; 1, 1) for 2 Tx/2 Rx antenna ports;  dH = dV = 0.5 λ |
| UE antenna configuration | 2 Tx/2 Rx antenna ports  Panel model 1: Mg = 1, Ng = 1, P = 2, dH = 0.5  (M, N, P, Mg, Ng; Mp, Np) = (2, 4, 2, 1, 2; 1, 1) for 2 Tx/2 Rx antenna ports;  dH = dV = 0.5 λ |
| UE antenna height | Follow the modelling of TR 38.901 (e.g. 1.5m) |
| UE antenna gain | 5dBi as starting point |
| BS Tx power | 23 dBm for 80 MHz bandwidth |
| BS receiver | MMSE-IRC as the baseline receiver |
| UE receiver noise figure | 10 dB |
| SCS | 120 kHz |
| Channel estimation | Ideal |
| UE power control | P0= -80; alpha = 1 |